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RESEARCH ARTICLE

Rediscovery of the enigmatic forest racer snake, *Dendrophidion boshelli* Dunn, 1944 (Serpentes, Colubridae): actions for the conservation of a critically endangered species

Redescoberta da enigmática cobra florestal Dendrophidion boshelli Dunn, 1944 (Serpentes, Colubridae): ações para a conservação de uma espécie criticamente ameaçada

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Abstract

Dendrophidion boshelli is a poorly known and endemic snake species from the Middle Magdalena river valley in Colombia. It was described in 1944 based on a single specimen from the municipality of Caparrapí, department of Cundinamarca. Since the original description, only three additional specimens have been established. As part of the results of a herpetological monitoring in the Miel I Hydroelectric project, department of Caldas-Colombia, three additional specimens of *D. boshelli* were found in 2014–2015. The specimens represent the second known population of the species. We presented morphological data and pholidosis; description of the coloration in life, and a description of the habitat. Recently, *D. boshelli* was included as a Critically Endangered (CR) species in the Red Book of

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Reptiles of Colombia, and the IUCN Redlist. For this reason, to promote the local conservation of this and other endemic and threatened species in the Miel I area, we suggested some actions at the local level, such as establishing a conservation area with legal status in the Middle Manso River basin, which is a tributary of the Miel I Hydroelectric project.

Resumo

Dendrophidion boshelli é uma espécie de cobra endêmica e pouco conhecida do meio do vale do rio Magdalena, na Colômbia. Esta serpente foi descrita em 1944 com base em um único espécime do município de Caparrapí, departamento de Cundinamarca. Desde a sua descrição, apenas três indivíduos adicionais são conhecidos. Recentemente, como parte dos resultados de um monitoramento herpetológico no projeto hidrelétrico Miel I, próximo à localidade-tipo, foram encontrados três exemplares adicionais de *D. boshelli*. Os exemplares representam a segunda população conhecida da espécie. Dados morfológicos, a descrição de sua coloração na vida e uma descrição do habitat são apresentados. Recentemente, *D. boshelli* foi incluída no Livro Vermelho dos Répteis da Colômbia na categoria Perigo Crítico (CR), e também para a Lista Vermelha da IUCN. Por ese motivo, para promover a conservação local desta e de outras espécies endémicas e ameaçadas na área do projeto Miel I, sugerimos algumas ações no nível local, como estabelecer uma área de conservação com status legal no rio Manso, que é tributario do projeto hidreléctrico Miel I.

Keywords

Colombia, endemic and threatened species, habitat preservation, Magdalena River valley, snakes

Palavras-chave

Colômbia, espécies ameaçadas, preservação de hábitat, serpentes, vale do rio Magdalena

Introduction

Compared to other vertebrates, snakes are still relatively unknown in many aspects of natural history, and consequently in their status of conservation (Greene 1997; Cundall and Greene 2000; Campbell and Lamar 2004; de Fraga et al. 2013). Some tropical ecosystems, such as rainforests, can support a high snake's diversity with some species reaching high local abundances (Martins and Oliveira 1998; Guimarães et al. 2014; Lynch 2015); however, an important proportion of species of the tropical snake's assemblages are considered rare species because they are barely observed and therefore poorly represented in scientific collections and literature (Lynch et al. 2016).

Snakes of the genus *Dendrophidion* Fitzinger, currently comprise 15 Neotropical species (Uetz et al. 2019). They are diurnal semi-arboreal colubrids with a body slightly compressed, dorsal scales keeled, head clearly differentiated from the neck, eyes prominent with rounded pupils, and with a very long tail (30–50% of the total length; Lieb 1988; Stafford 2003; Freire et al. 2010; Cadle, 2012a, b; Cadle and Savage 2014). This genus is distributed from southern Mexico to Bolivia (Lieb 1988; Freire et al. 2010; Natera et al. 2015). *Dendrophidion boshelli* Dunn, 1944, is a forest racer snake only known by three individuals collected at the type locality in the

middle Magdalena River valley, Colombia (Dunn 1944; Caicedo-Portilla and Lynch 2015). The intra-generic relationships of *D. boshelli* are poorly understood, given that it is categorized as *incertae sedis* in the genus by Lieb (1988). Similarly, there is insufficient information about its natural history. It is suspected that, like other species of the genus, *D. boshelli* is a stream-dwelling species that feeds on anurans (Cadle 2012b; Caicedo-Portilla and Lynch 2015). Since it is only known from the type locality, and a nearby heavily intervened area in Colombia, *D. boshelli* was recently categorized as Critically Endangered (CR) in the IUCN Redlist (Caicedo et al. 2017), and included in the Red Book of reptiles of Colombia (Caicedo-Portilla and Lynch 2015).

Here, we present the discovery of a new population of this species, expanding the knowledge by providing new morphological data and a distribution and habitat update. Also, we present the first photographs in life of the species. We also propose a series of steps to promote the protection of the habitat for this and other vertebrate endangered species, in the Middle Manso River basin, department of Caldas, Colombia.

Methodology

During 2014–2015, more than 400 effective sampling hours were invested in monitoring the diversity and distribution of the herpetofauna in the Manso River, which supplies the Miel I Hydroelectric Power Plant, at the east of the department of Caldas (Figs 1, 2). During fieldwork, we registered three specimens assignable to the snake *D. boshelli*. The identification was made after reviewing the specimens and comparing them with the holotype (Instituto de Ciencias Naturales, ICN-10117) and the original description (Dunn, 1944). All three specimens were collected under the research permit granted by the pertinent environmental authority (Corporación Autónoma Regional de Caldas - Corpocaldas), and housed in the herpetological collection of the Natural History Museum at the Centro de Museos of the Universidad de Caldas (MHN-UCa) (Table 1). Snout vent length (SVL) and Tail length (TL) were registered with a ruler to the nearest mm. Temperature and humidity were registered with an Extech thermo-hygrometer. Ventral and sub-caudal counts follow Dowling (1951). Sex was determined on the basis of presence/absence of hemipenis verified through a ventral incision at the base of the tail.

Habitat of the new located population. Records come from the adjacent area to the entry point of the Manso River transfer (5.608767N; -74.955333W, WGS84, 650 m), La Sonrisa village, "Corregimiento Berlín", municipality of Samaná, department of Caldas, Colombia. This area is 55 km north-west from the type locality (Fig. 1). Upstream vegetation of the Manso River transfer belongs to a mature forest in good conditions, currently interrupted by trails in its interior, as well as livestock and agricultural crops (e.g. Avocado and coffee, *Persea americana* and

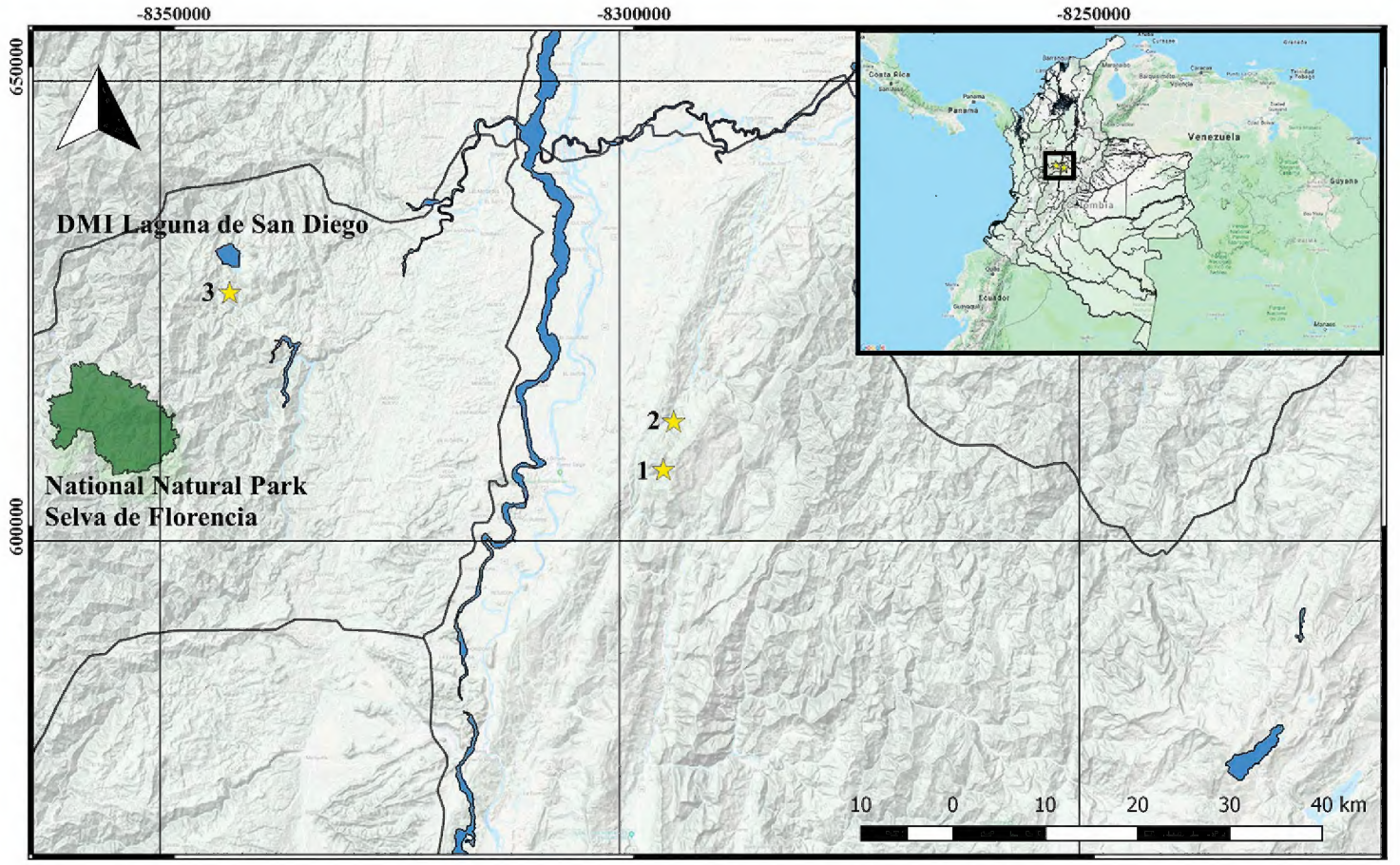

Figure 1. Map of the known distribution of *Dendrophidion boshelli*. (**1**) Type locality, Volcanes village, municipality of Caparrapí, department of Cundinamarca. (**2**) El Valiente village, municipality of Caparrapí, department of Cundinamarca. (**3**) New record, Manso River transfer, La Sonrisa village, municipality of Samaná, department of Caldas, Colombia.

Table 1. Morphometric characters and scale counts of *Dendrophidion boshelli* specimens from Manso River, municipality of Samaná, department of Caldas, Colombia. Characters impossible to be precisely recorded due corporal damage are marked with an asterisk (*).

Character	ICN 10117 (Holotype, ♀)	MHN-UCa 239 ♂	MHN-UCa 263 ♂	MHN-UCa 271 ♂
SVL (mm)	253	419	480	531
TL (mm)	56 *	*	340	369
TC/SVL	–	–	0.72	0.69
Dorsals	15-15-15	15-15-15	15-15-15	15-15-15
Ventrals	135	136	136	141
Subcaudals	37 *	133	134	128
Preoculars	1-1	1-1	1-1	1-1
Post-oculars	2-2	2-2	2-2	2-2
Temporals	2+2	2+2	2+2	2+2
Supralabials	8/9 (4–6)	9/9 (4–6)	8 (3–5)/9 (4–6)	9/9 (4–6)
Infralabials	10/ 9 (1–6)	9/ 9 (1–6)	9/ 9 (1–6)	9/9 (1–6)
Preventrals	3	3	3	3
Gulars	3	4	4	3
Cloacal plate	Undivided	Divided	Divided	Divided
Dorsocaudal reduction	–	*	8>6, 14–15	8>6, 20–21

Coffea arabica, respectively), towards the hilltops of the mountains (Fig. 2). Such activities necessarily involve the intervention of the forest and, as a consequence, there is extraction and selective use of wood. The forest has a continuous canopy by

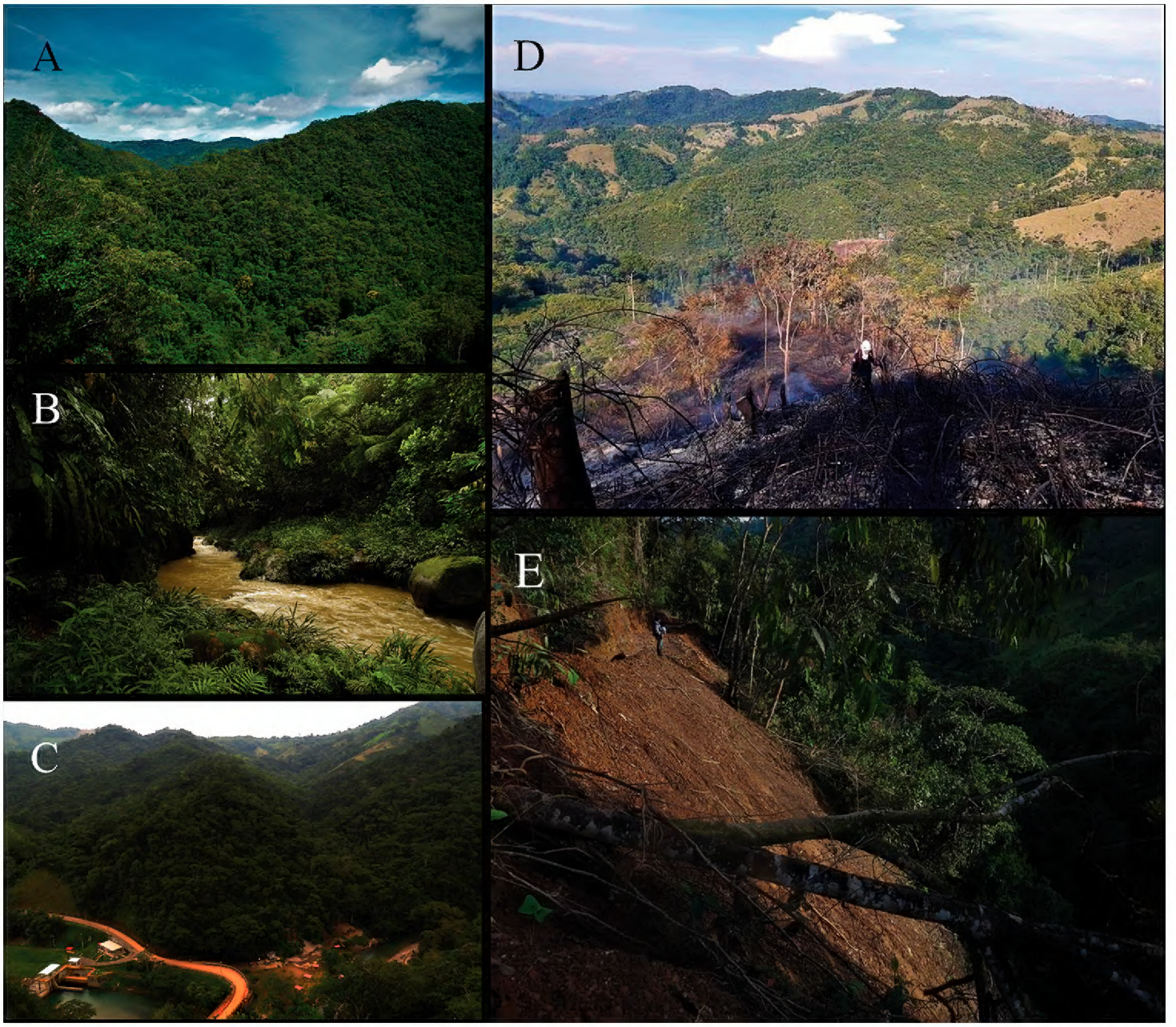

Figure 2. Habitat of *Dendrophidion boshelli* in the Manso River basin, La Sonrisa village, municipality of Samaná, department of Caldas, Colombia. (**A**) Panoramic view of the general habitat (**B**) Interior of the forest (**C**) Manso River at the point of transfer (**D**) Recent burning -September 2019- to expand agricultural areas (**E**) Recent intervention -open road- inside the primary forest. Photographs: Julián Andrés Rojas and Mateo Marín.

and large, with five strata in its vertical structure and trees of up to 30 m. A rich and well-formed understory is present. This forest is characterized mainly by the abundance and dominance of palms (*Geonoma*, *Oenocarpus* and *Welfia*; Arecaceae), in addition to a high abundance of riparian vegetation belonging to the genera *Asplundia*, *Cyclanthus*, *Dicranopygium* (Cyclanthaceae), and *Costus* (Costaceae). Humidity varies between 54–88% and temperatures between 23–29 °C, in addition to a precipitation between 3500–4000 mm per year (Díaz-Ayala and Zuluaga-Isaza 2015). Interior conditions include vegetation species of advanced state of succession, such as *Pleurothyrium* sp. (Lauraceae), *Virola sebifera* (Myristicaceae), *Welfia regia* (Arecaceae), *Compsoneura mutisii* (Myristicaceae), *Geonoma* sp. (Arecaceae), among others. This area belong to the Pre-montane Tropical Forest life zone (bp-PM) *sensu* Holdridge (1982), or to the Middle Magdalena Tropical-humid Zonobiome (Rodríguez et al. 2006).

Results

The first snake (MHN-UCa 0239; SVL 419 mm, tail broken) was registered on 18 May 2014 at 11:35 h, road killed 150 m above the Manso River transfer site. The second individual (MHN-UCa 0263; SVL 480 mm, TL 340 mm; Fig. 3) was registered on 2 December 2014 at 09:20 h, resting on a hollow at 1.7 m high in a wall of rock on the edge of the Manso River. The third individual (MHN-UCa 0271; SVL 531 mm, TL 369 mm) was found on 4 April 2015 at 20:00 h (28.7 °C, 82% relative humidity), perched on a bush branch 1.47 m above the ground and >100 m away from the river. The three specimens are adult males and present a similar coloration, consisting of a light green back on the anterior part of the body -including the head-, being yellowish towards the edge of the ventral scales; the back turns reddish with brown tones later from the first 1/6 of the total length until the tip of the tail (Fig. 3). On their backs all the specimens present 79–84 black stripes crossed transversely, of less than a scale wide and reaching up to the fourth row of dorsal scales. These crossed black stripes have at their ends and in the spaces between scales, a bright yellowish green spot. The belly is uniformly yellow from the second pre-ventral scale to the tip of the tail, but has a more vivid tone towards anterior part of the venter (Fig. 4). Lateral edges of the ventral scales present a black spot, forming almost a continuous line in the anterior part of the body because the spots cover almost the entire edge of the scales (Fig. 3). The head is olive green dorsally, turning brown in the scales that border the orbit. Supra and infra-labial scales are white, with light orange spots concentrated on the edge, which is only observable at close range; a black line borders the upper part of all the supra-labial scales, being more conspicuous posteriorly (Fig. 3). *Dendrophidion boshelli* is found in sympatry with congenerics *D. percarinatum* and *D. bivitattum* in the Manso River.

Threats to the conservation of Dendrophidion boshelli. Currently, although it is difficult to determine how affected this species may be in the Manso River area, due to the lack of sufficient population data – only three individuals for more than 400 h of survey – different anthropogenic factors may be recognized as a threat to the species in the near future. The expansion of grazing land for cattle breeding is the main factor leading to deforestation in the Manso River habitat. In addition, near this area Uranium exploitation is planned, for which the forests bordering the river could be intervened by the construction of more roads and the movement of people and heavy machinery (Fig. 2E). This interference in this habitat directly affects the associated biodiversity, which include different vertebrate endemic and threatened species (Fig. 5), some of which are monitored with a functional connectivity approach at the landscape scale, supported by ISAGE S.A. In addition, one of the registered individuals of *D. boshelli* was road killed on the road that leads to the point of the river transfer. As this is a diurnal and terrestrial snake's species, it may be more susceptible to vehicular run-over than other snakes, as has been observed in other Neotropical forests (i. e. Hartmann et al. 2011; Maschio et al. 2016).

Figure 3. Adult male of *Dendrophidion boshelli* from the Manso River, La Sonrisa village, municipality of Samaná, department of Caldas, Colombia (MHN-UCa 0263; SVL 480 mm, TL 340 mm). Photographs: Julián Andrés Rojas.

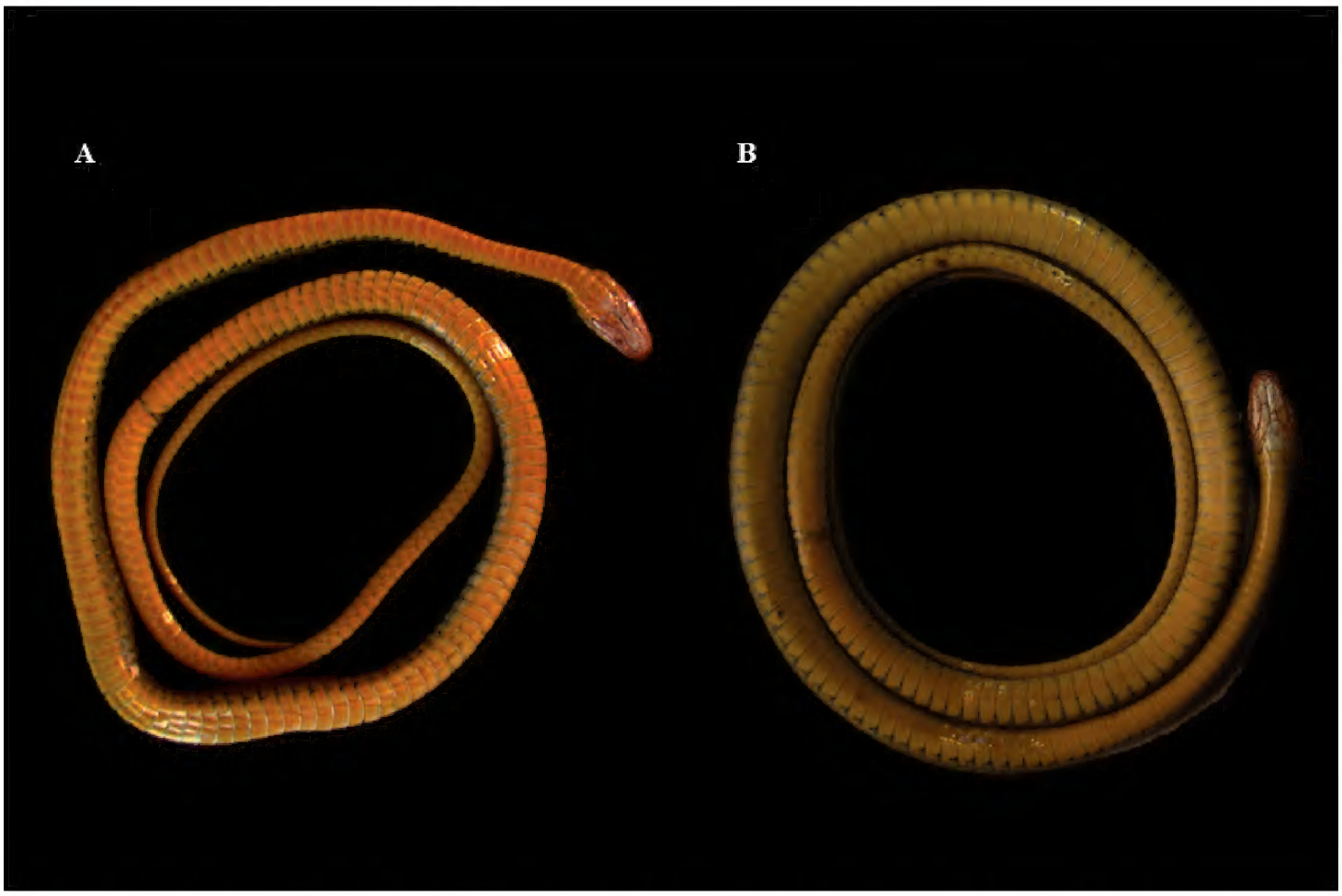

Figure 4. Photographs showing ventral coloration in newly euthanized individuals of *Dendrophidion boshelli*, (**A**) MHN-UCa 0263; (**B**) MHN-UCa 0271. Photographs: Julián Andrés Rojas.

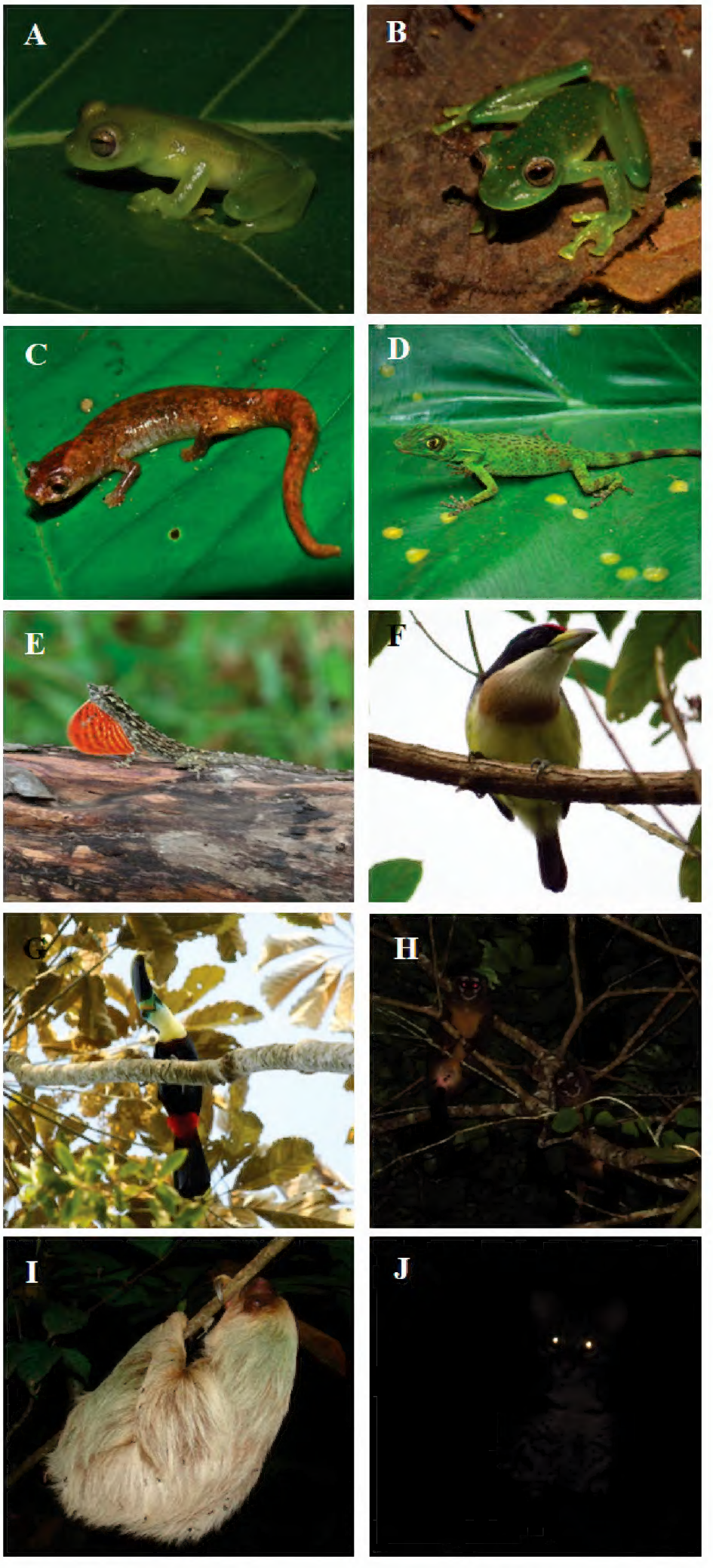

Figure 5. Endemic and threatened vertebrate species from the Manso River transfer point, municipality of Samaná, department of Caldas, Colombia. (**A**) *Rulyrana susatamai*, (**B**) *Sachatamia punctulata*, (**C**) *Bolitoglossa lozanoi*, (**D**) *Anolis limon*, (**E**) *Anolis sulcifrons*, (**F**) *Capito hypoleucus*, (**G**) *Rhamphastos vitellinus*, (**H**) *Aotus griseimembra*, (**I**) *Choloepus hoffmanni*, (**J**) *Leopardus pardalis*. Photographs: Raúl Gil (**F, G**), Julián Andrés Rojas (**A, B, C, D, E, H, I, J**).

Discussion

In recent years, some species of snakes have been rediscovered in Colombia (i.e. *Atractus wagleri*, Passos & Arredondo, 2009; *Trilepida joshuai*, Rojas-Morales & González-Durán, 2011; *Coniophanes andressensis*, Caicedo-Portilla, 2014; *Imantodes phantasma*, Medina-Rangel et al., 2018; Vanegas-Guerrero et al., 2019), which should promote the need for field studies to monitor populations of these little-known species. The recording of species after several decades since the last known description is a relatively common case for snakes. Some species are difficult to find because they occupy hidden microhabitats, live in inaccessible places or have low densities, among other factors (Henderson et al. 1988; Greene 1997; Curcio et al. 2002; Sawaya et al. 2008; Medina-Rangel et al. 2018). In addition, many localities are only sampled a few times with long intervals between field surveys.

Caicedo-Portilla and Lynch (2015) suggested that *D. boshelli* may be affected by the decrease in amphibians, as has been suggested for other species in the genus *Dendrophidion* (Cadle 2012b). Rio Manso has registered the greatest diversity of amphibians compared to other sites in the area of the Miel I Hydroelectric project (Díaz-Ayala and Zuluaga-Isaza 2015). This could corroborate what was proposed by Caicedo-Portilla and Lynch (2015), indicating a possible relationship between the presence of *D. boshelli* and a diverse amphibians assemblage. It should be noted that in the Manso River we also recorded other species of snakes that inhabit well preserved habitats (e.g. *Oxyrhopus occipitalis*, *Scaphiodontophis annulatus*) (Rojas-Morales et al. 2018). Currently, the information about the distribution of *D. boshelli* is still inconclusive, and it is possible that this species has a wider distribution along the Middle Magdalena River, encompassing the lowland and pre-montane humid forests of the Eastern and Central Cordilleras in Colombia. Their presence is estimated likely in areas such as primary forests of the Serranía of the Quinchas (department of Boyacá), the Samaná and Claro rivers canyons (departments of Antioquia and Caldas), and as far to the north to reach Serranía of San Lucas.

Compared to other more charismatic animals, such as birds and mammals, snakes have received little scientific attention to develop conservation programs and strategies (Mullin and Seigel 2009). There is a strong argument from a scientific perspective that, in practice, the critical issue generally boils down to the preservation of habitat. If the habitat is retained, the snake -or other- population will generally persist; whereas if the habitat is lost, so is the population of interest (Seigel and Mullin 2009). Thus, we strongly advocate for the legal protection of the representative habitat of *D. boshelli* in the Manso River, as the essential core of any broad conservation initiative.

Conclusions

Although there are good habitat conditions in the area of the detected population, there is no legal conservation target figure that guarantees its permanence over time, and therefore it is susceptible to human intervention (e.g. conversion of the ecosystem for the establishment of crops and roads), as observed during years 2018–2019

(Fig. 2D, E). Approximately 4 km to the north of the Manso River, exists the "Distrito de Manejo Integrado Laguna de San Diego", which is a non-restricted conservation area for recreational and touristic purposes. For this reason, to mitigate the possible negative impacts in the short term, we suggest the following conservation actions at the local level:

- Establishing a conservation area with vested legal status for the Middle Manso River basin, with the justification of preserving endemic and threatened biodiversity, as well as the water resource for hydroelectric generation. We propose the figure of "Protective Forest Reserve" in the terms of Decree Law 2811 of 1974, National Code of Renewable Natural Resources and Protection of the Environment, Art. 204., which defines protective forest area as: "the zone that must be conserved permanently with natural or artificial forests, to protect these same resources or other renewable natural resources. In the protective forest area, the protective effect must prevail and only the secondary fruit of the forest will be allowed to be obtained". We propose the delimitation and protection of 756 ha around the transfer point of the Manso River, covering the forest and headwaters of streams and creeks that drain to the river (Fig. 6).
- Restoring structural connectivity between the forest fragments of the Manso river basin with the National Natural Park Selva de Florencia and DMI Laguna de San Diego to facilitate the flow of fauna and flora through this area.

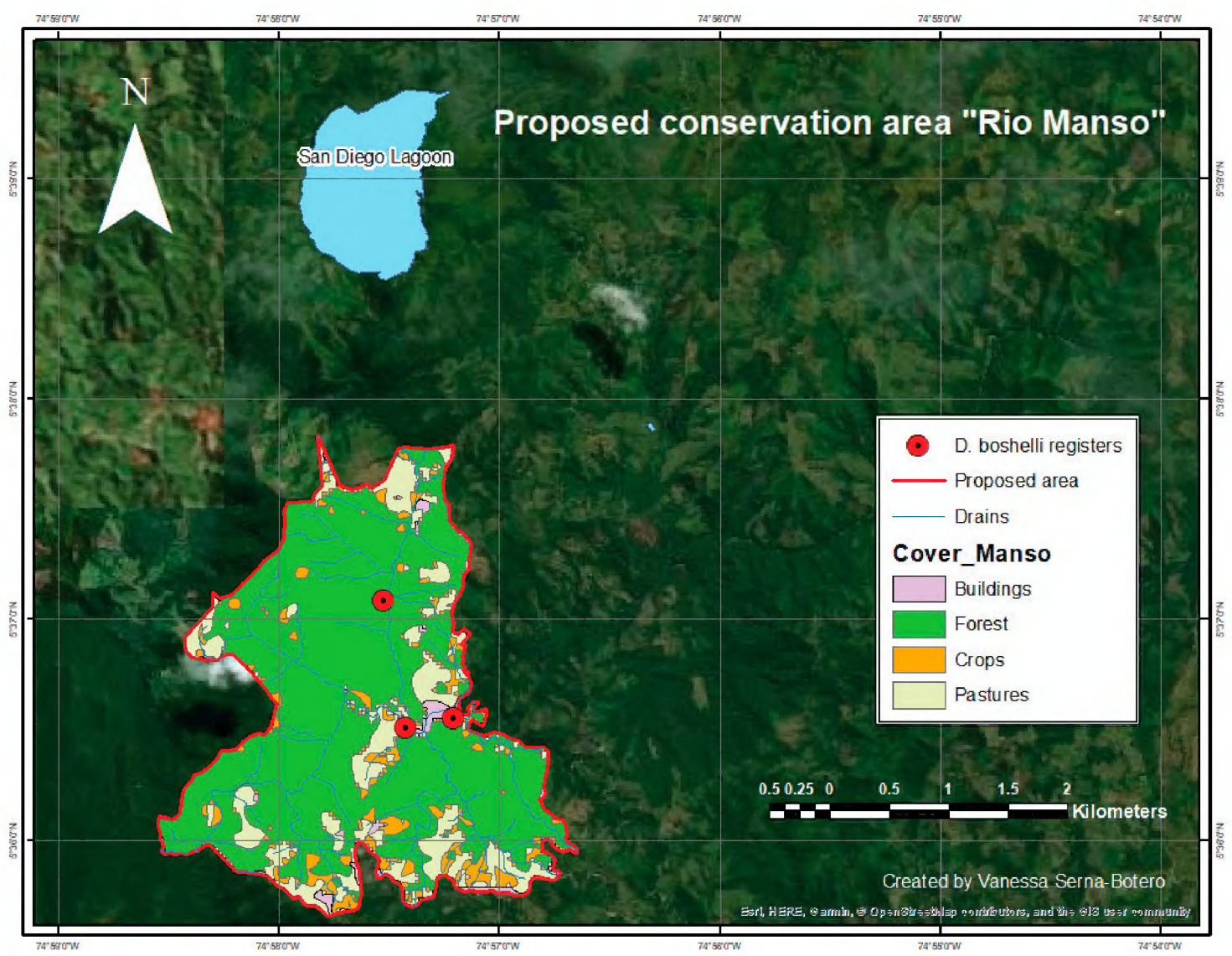

Figure 6. Proposed conservation area for the habitat of the Middle Manso River basin, municipality of Samaná, department of Caldas, Colombia. Map edition was based on a Landsat 8 image of August, 2018.

- Promoting the establishment of visual signals to announce the presence of threatened wildlife in the vicinity of the area of Miel I Hydroelectric project. This seems to be an action to reduce vertebrate mortality from road kill. Road kill mortality has not been evaluated locally and deserves specific research.
- Developing a *Dendrophidion boshelli* focused monitoring plan, in order to know local density and ecological traits for local conservation strategies. This is necessary to know how this species is influenced locally in relation to environmental changes and habitat availability.

We call attention to the non-mining exploitation around the Manso River by the U308 Corp, in the "Corregimiento Berlín".

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